

# Improving the Creation of Silicone Fingertips for the 3D Printed Victoria Hand

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## Abstract

Victoria Hand Project (VHP) is an organization that designed a 3D printed prosthesis with silicone cast around its fingertips [1]. Currently, the process is unreliable and tedious, requiring a 48-hour curing time [2]. The goal of the project is to research silicone-based materials and molding methods to improve the quality of the silicone fingertips and streamline the overall process. The design objectives were to minimize silicone curing time, improve cosmetic appearance, maintain affordability, allow color matching, maintain durability, and improve the reliability of the molding process and final results. After testing various methods of silicone molding, it was determined that the silicone should be heated before injection and that fingertips be vacuum degassed in two layers for 15 minutes each time with the original mold. The recommended releasing agent is still Vaseline. Of the final prototypes of fingertips, 5 of 6 design objectives were achieved. The final prototype did not reduce curing time since initial mold modifications proved ineffective, and the team decided to prioritize improving the cosmetic quality of the fingertips for greatest user impact. To provide a more accessible solution for VHP's partners, a vacuum chamber was constructed from a pressure cooker and hand pump as a simple alternative to buying a commercial vacuum system. The prototype was able to reach and hold a pressure of -23inHg for 10 minutes until a small leak developed around the tubing. Nonetheless, the prototype is a viable solution for use as a vacuum chamber and will improve the quality of the fingertips for VHP.

## Background

- VHP is an organization that designed the Victoria Hand, a "low-cost, highly functional, 3D printed [prosthesis]" for amputees [1].
- VHP partners with clinics in developing countries and trains local healthcare providers to fit amputees after providing the necessary 3D printing technology [1].
- VHP has 10 global partners including Haiti, Guatemala, and Ecuador [1].
- The current prosthesis design is 3D printed with black polylactic acid (PLA).
- The fingertips are molded with silicone for grip [2].
- Approximately 20% of fingers and 50% of thumbs produced have cosmetic defects that render them unusable.
- A cosmetic defect is defined as air pockets at the surface of the silicone fingertip that create holes and craters that reduce the overall aesthetic of the fingertip.
- Considering the curing time of at least 48 hours, the unreliability of the current process leads to wasted materials and time [2].

## Social Impact and Potential User Base

Amputees experience a feeling of loss and grief when they lose a limb or a portion of a limb. The visual of an aesthetically pleasing prosthetic can enhance positive feelings, promote acceptance of a new prosthetic, and cause positive psychological effects for the amputee [3].

The potential user base of this project will directly be individuals who work at VHP clinics around the world. It will indirectly affect anyone who receives hands from VHP.

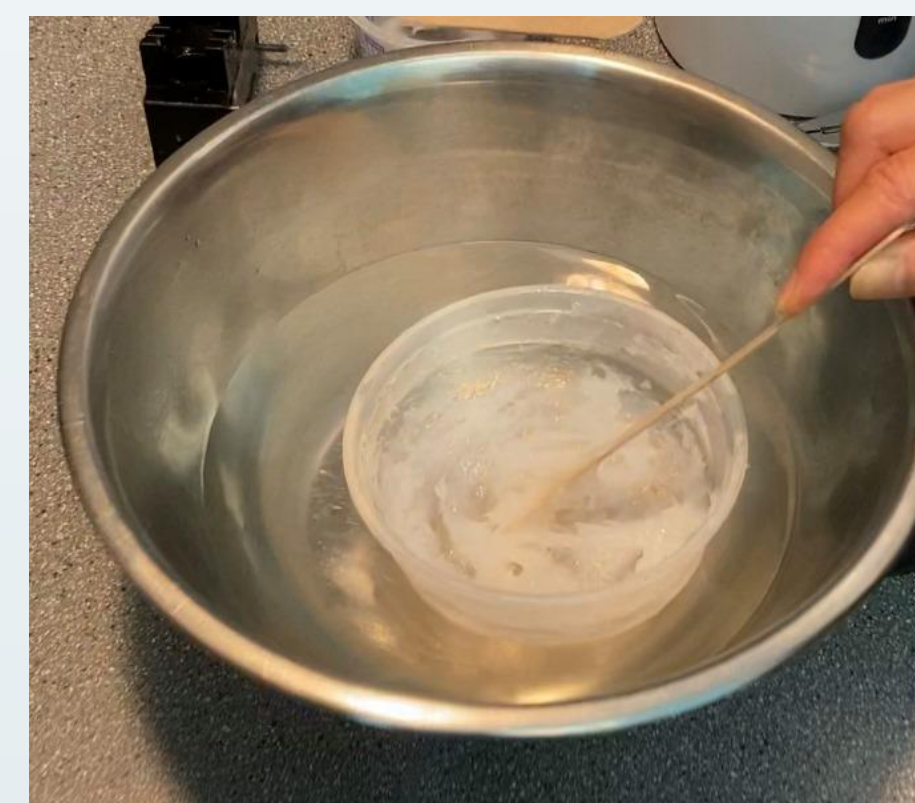
## Methodology

### Design Objectives

1. Curing time must be < 48 hours
2. Fingertips must have < 3 holes of < 1 mm in diameter per finger and 0 holes > 1 mm in diameter
3. Cost increase must be < 10%
4. Silicone can be color matched
5. Fingertips must be at least as durable as the current fingertips and last 2-3 years
6. 90% of fingertips must be acceptable

### Constraints

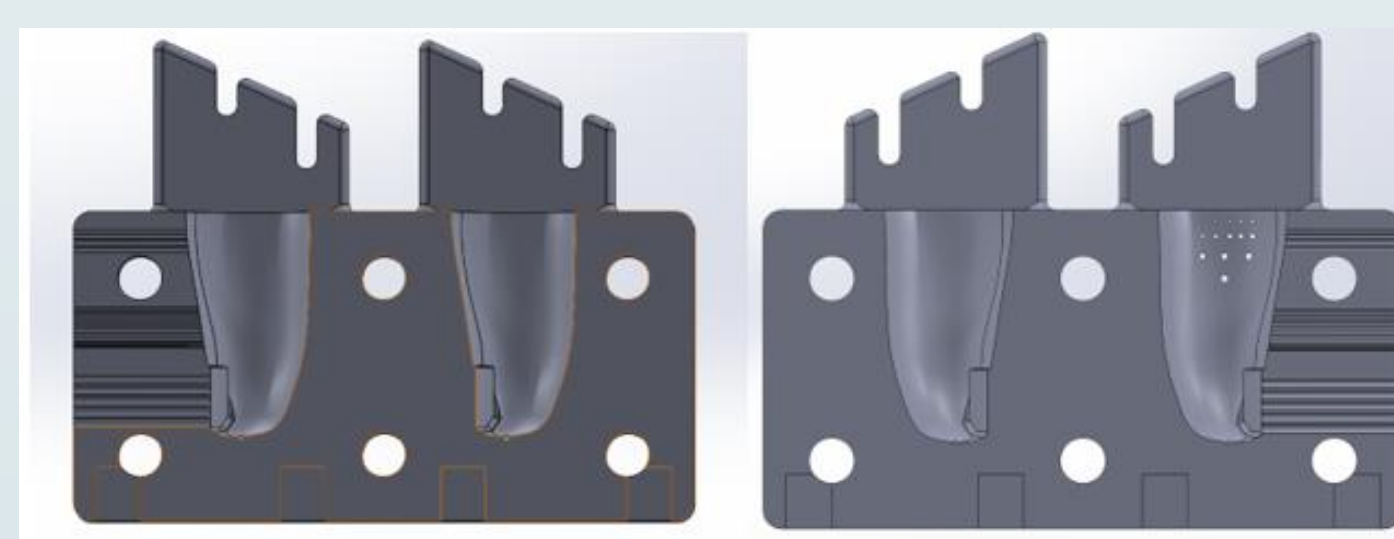
1. The silicone molds must be 3D printable.
2. The solution should not require changes to the prosthesis itself.
3. The solution must be affordable for VHP's partners.
4. The solution must be accessible for VHP's partners.
5. The solution must be food safe.
6. The project should be complete by March 25th.



Silicone was heated with a hot water bath to reduce viscosity

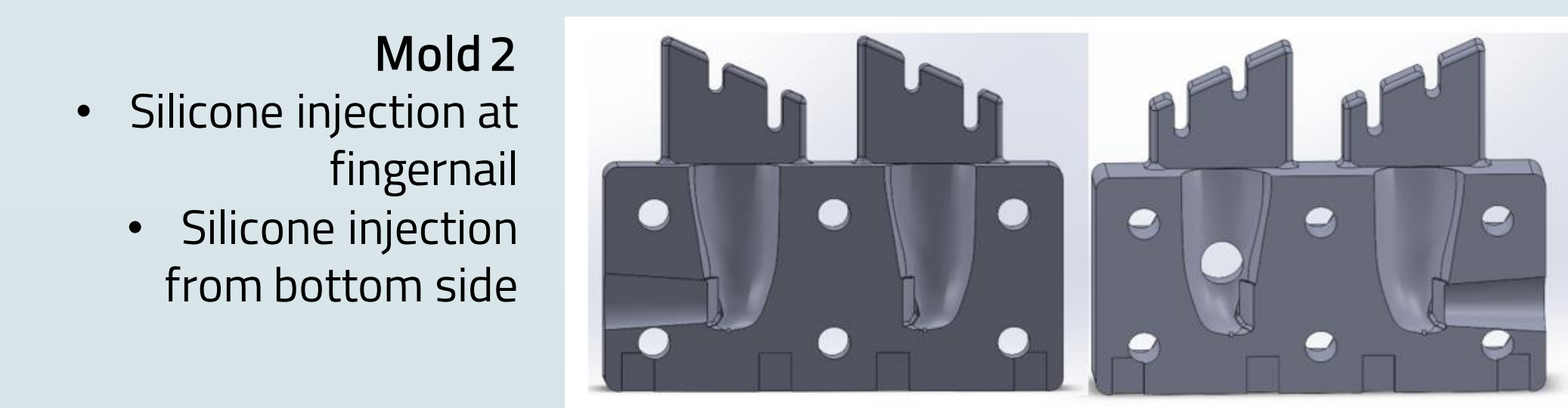


Silicone was degassed before and after injection into the molds



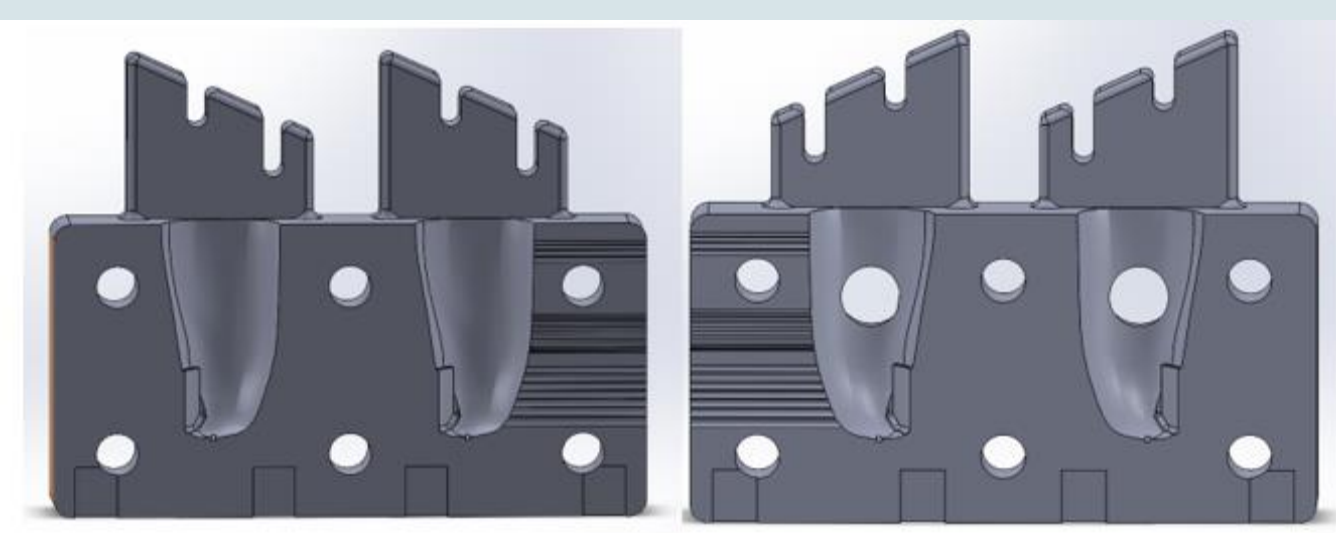
### Mold 1

- Air holes along seam and on side
- Control



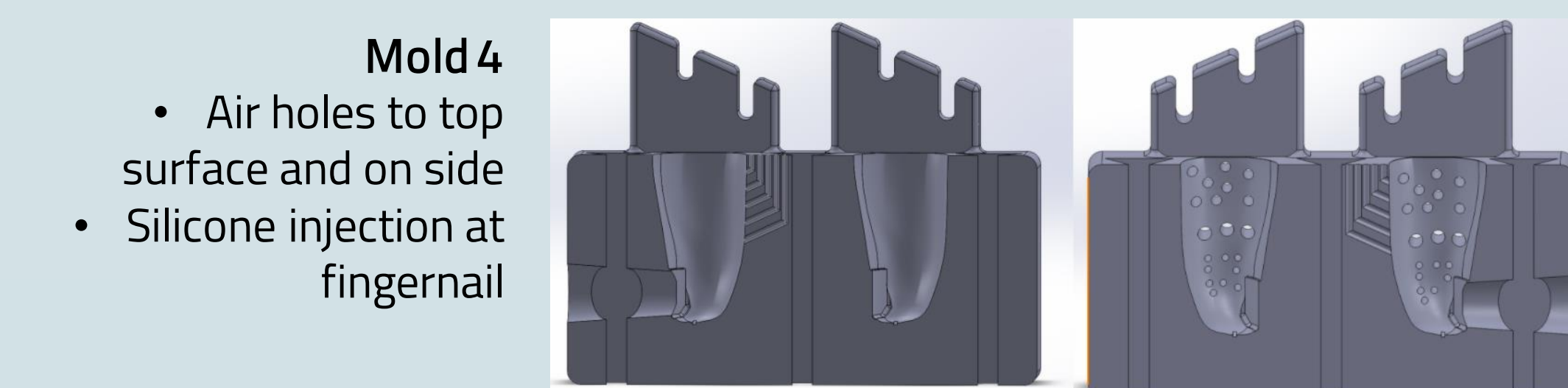
### Mold 2

- Silicone injection at fingernail
- Silicone injection from bottom side



### Mold 3

- Air holes along seam
- Silicone injection from upper side

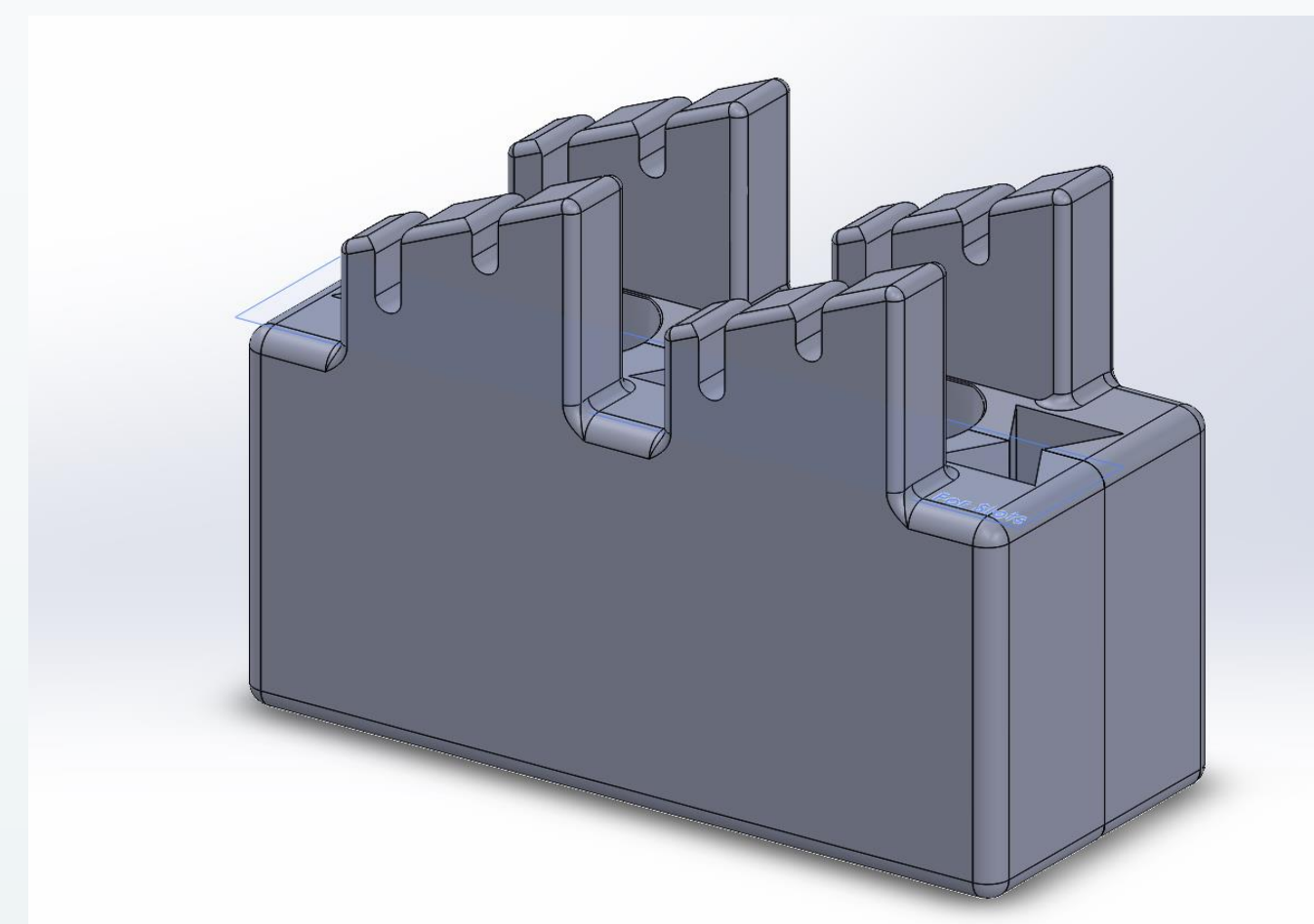


### Mold 4

- Air holes to top surface and on side
- Silicone injection at fingernail

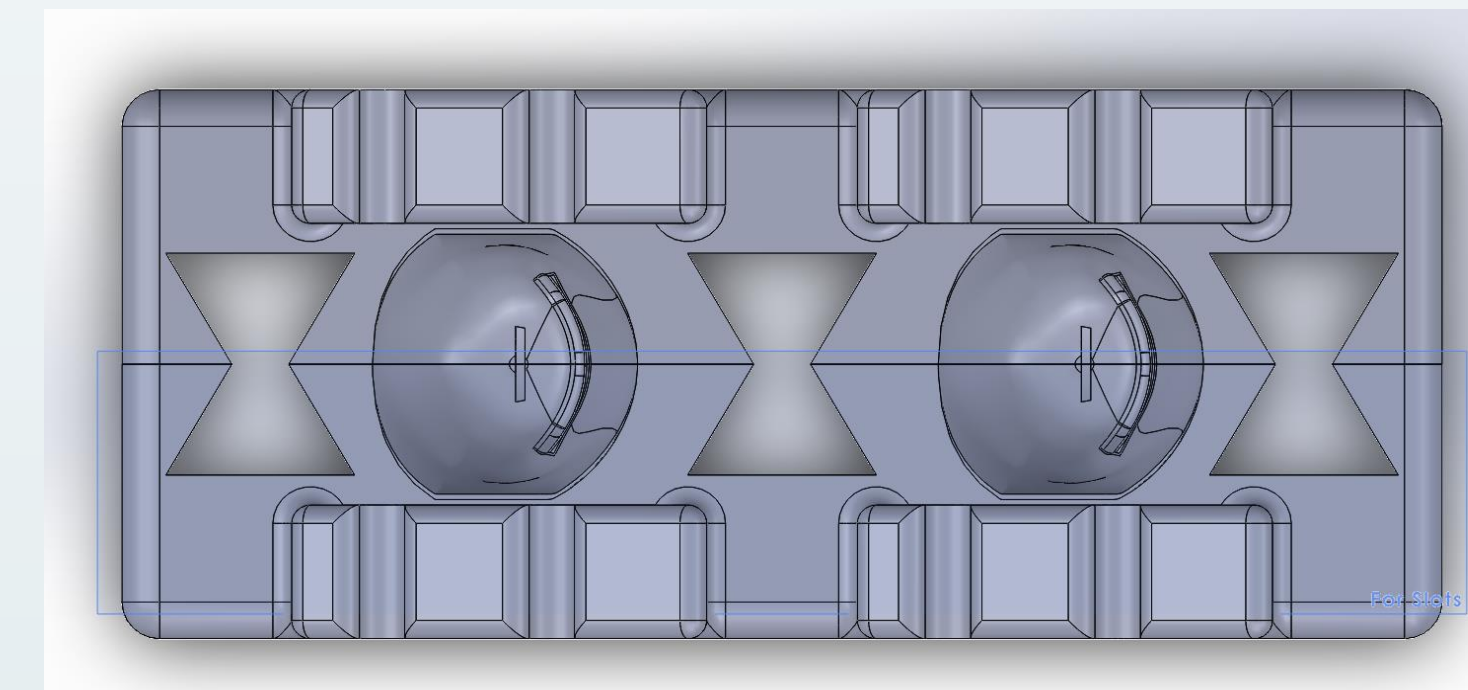
## Results

Despite efforts to produce better quality fingers through the modifications of the molds, this was not achieved. The best fingertips with the fewest surface defects were produced from unmodified molds. As a result it is recommended to continue to use the current VHP finger molds.



Current VHP Mold  
Isometric View

### Current VHP Mold Top View



Decreasing the viscosity of the silicone using a hot water bath before degassing in a vacuum chamber generated the best fingers. While some air pockets were still present beneath the surface, there were few to none surface defects or extrusions.

The use of a hot water bath is an effective and inexpensive solution for VHP. However, a commercial vacuum degasser is not affordable; therefore, it is not a viable solution for VHP and its global partners. To address this problem, we prototyped a custom-made degasser using a pressure cooker and a hand pump.



Finger Produced from Mold 1 with Reduced Viscosity and 2x Degassing



Produced with Reduced Viscosity Silicone

## Conclusion

The best molding method is to:

1. Heat the silicone before injection to reduce viscosity
2. Apply a thin layer of Vaseline to the inner surface of the original mold
3. Inject the silicone into the molds until they are half-filled
4. Vacuum degas the mold at -25 inHg for 15 minutes
5. Inject the rest of the silicone and degas for another 15 minutes
6. Insert the fingertip and let cure for 48 hours

## Final Prototype

### Materials

- Sealable container (e.g., pressure cooker)
- Hand vacuum pump
- Tubing
- Silicone



Custom-Made Vacuum Degassing System



Fingertip Produced via Recommended Molding Method

## Future Work

- Reduce volume of vacuum chamber
- Add additional pump and/or use a more ergonomic pump
- Reduce curing time by increasing the humidity of the curing environment

## Acknowledgements

We would like to acknowledge Dr. Nikolai Dechev for his work with VHP and continued support for students. Thank you for being our faculty supervisor for this project.

We would like to thank Michael Peirone for his continued assistance and support throughout the project. Your guidance and professionalism were immensely appreciated.

We would like to thank Evan Stefanek and Ian Fraser for allowing us to use a vacuum chamber and offering their assistance throughout the duration of this project.

## References

- [1] Victoria Hand Project, "Victoria Hand Project," 2019. [Online]. Available: <https://www.victoriahandproject.com/>. [Accessed 18 March 2021].
- [2] Victoria Hand Project, Manual F: Making Silicone Fingertips For the Victoria Hand, Victoria: Victoria Hand Project, 2018.
- [3] A. W. A. M. A. B. Stefania Sansoni, "The Aesthetic Appeal of Prosthetic Limbs and the Uncanny Valley: The Role of Personal Characteristics in Attraction," International Journal of Design, vol. 9, 2015